

MEMORANDUM

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TO: Sean Sheldrake, On-Scene Coordinator, EPA, Region 10, Seattle, WA, ECL-113

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THRU: Jeffrey Fowlow, P.G., START-2, E & E, Seattle, WA

SUBJ: Alder Mine Contaminated Well Water Removal Assessment
Twisp, Washington

REF: Contract No. 68-S0-01-01
Technical Direction Document No. 02-01-0007

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SECTION 1: PURPOSE AND AUTHORIZATION

The purpose of this removal assessment (RA) memo is to determine if there is sufficient data to justify a non time-critical removal action at an area just outside Twisp, Washington (Figure 1), where contaminants have been detected in residential wells. This RA memo also will discuss alternatives and recommend a course of action. The memo is organized into the following sections:

- Section 1: PURPOSE AND AUTHORIZATION
- Section 2: DEFINITION OF PROBLEM
- Section 3: HISTORY OF PROBLEM AREA
- Section 4: PREVIOUS STUDIES
- Section 5: ALTERNATIVES
- Section 6: DISCUSSION/COMPARISON OF ALTERNATIVES
- Section 7: RECOMMENDATIONS
- Section 8: REFERENCES

This RA is authorized under Contract No. 68-S0-01-01, Technical Direction Document No. 02-01-0007, as part of Superfund Technical Assessment and Response Team (START)-2 contract between Ecology and Environment, Inc. (E & E) and the United States Environmental Protection Agency (EPA) Region 10.

SECTION 2: DEFINITION OF PROBLEM

Analytical testing of wells in the area has revealed levels of contamination exceeding maximum contaminant levels (MCLs) for certain heavy metals in some residential wells near Twisp, Washington. Contaminants that have exceeded MCLs include antimony, lead, and arsenic. As discussed later, arsenic is the only contaminant that can be associated with mining-related activities in the area. Furthermore, arsenic is believed to be the only contaminant that consistently shows up above MCLs in certain wells. Arsenic contamination is discussed further in Section 4.

Arsenic has become much more of a concern recently because EPA is reducing the MCL from 50 micrograms per liter ($\mu\text{g/L}$) to 10 $\mu\text{g/L}$, fully effective in the year 2006.

Arsenic is found in the environment in several forms. In water, arsenic typically is found as trivalent arsenite ($\text{As}(\text{III})$) or pentavalent arsenate ($\text{As}(\text{V})$). $\text{As}(\text{V})$ has a negative charge and typically is found in aerobic surface waters. $\text{As}(\text{III})$ is neutral in charge and typically is found in anaerobic groundwater. Since $\text{As}(\text{III})$ is neutral in charge, it is more difficult to remove from water than $\text{As}(\text{V})$ (EPA 2002).

SECTION 3: HISTORY OF PROBLEM AREA

There are several mines in the area near Twisp, Washington. The Washington State Department of Ecology (Ecology) is studying or pursuing three abandoned mine facilities in the area. These are Alder Mine, Alder Mill, and Red Shirt Mill. Red Shirt Mill is east of the Methow River and is likely not contributing to the contaminated wells, which are all west of the river. Alder Mine lies near the headwaters of Alder Creek, which is in a separate watershed from the area where the arsenic-contaminated wells are located. Alder Mill is located about 3 miles northeast from the Alder Mine, in a separate watershed that also contains the arsenic-contaminated wells.

Alder Mine operated intermittently from 1910 to 1953 (E&E 2000). Activities since the mine ceased operation are included in Section 4.

SECTION 4: PREVIOUS STUDIES

Published studies are listed in Section 8. There are ongoing studies being performed by the Okanogan County Health Department (OCHD) and Ecology. Reports have not been prepared, but data has been made available to EPA and START-2.

There are various letters and e-mails in the record that will be cited during this discussion.

Helen Krinke, in a letter to Ecology dated December 15, 1980, describes some of the early history of Alder Mill operations and describes a failure of a tailings dam that reportedly ruined her well and vegetation in the area. This reportedly occurred in 1952 (SAIC 1993). This letter is included in the 1986 Ecology Site Inspection Report.

Ecology performed a site inspection (SI) of the mill site in 1986.

The Science Applications International Corporation (SAIC) performed a supplemental SI of the mill site in 1993.

E & E performed a preliminary assessment (PA)/SI of the mine site in 2000.

A study, believed to be a master's thesis, was performed by D. Peplow and Robert Edmonds. It was published by the University of Washington in 2001. Although the data in this study identified wells by number only, subsequent e-mails between Mr. Peplow and Ecology identify the data by owner or user. This data will be referred to as the Peplow data.

Sampling to date has focused on water drawn from domestic wells and from springs. A small percentage of the total data come from spring samples. Mostly the data come from wells identified by the name of the current owner and user at the time of the sampling event. This leads to some confusion, as owners and users have changed. Furthermore, OCHD has determined latitude and longitude of the wells they sampled using Global Positioning System. There are other latitude and longitude values in the Peplow data that do not match the OCHD data. Therefore, there are uncertainties about the location of some of the wells.

All available well contaminant data for arsenic, antimony, and lead are listed in Table 1. Data was screened as described below and those data that passed the screening are included in Table 2.

The first definitive data concerning the contaminated wells are contained in the Ecology 1986 SI. Samples collected from the Krinke, Jolley, and Clark wells were analyzed for arsenic, copper, and zinc. Arsenic was detected in these three wells at concentrations of 10, 30, and 15 µg/L, respectively. The location of the Krinke well has been identified. The locations of the Jolley and Clark wells are uncertain, although there is a property owner named Jolley located southeast of the Alder Mill site. Because the Jolley and Clark wells have not been located, the Jolley and Clark well data have been excluded from Table 2.

The SAIC supplemental SI added no data pertinent to the groundwater contamination.

Two groundwater samples were collected during the E & E PA/SI at Alder Mine. One of the groundwater samples was collected from the White well, adjacent to the Alder Mill site. The other groundwater sample was collected from a seep near the Alder Mine site. Arsenic and lead were detected in the seep sample at concentrations of 2.3 µg/L and 3.1 µg/L, respectively. Antimony was not analyzed for in the seep sample. Arsenic and lead were detected in a background sample collected upgradient and southwest of the mine at concentrations of 1.1 µg/L and 0.19 µg/L, respectively. Antimony was not analyzed for in this background sample. The sample at the mine seep is not included on Table 2. However, it appears evident that, based on the concentration of arsenic at the mine seep, Alder Mine is not contributing to the elevated arsenic levels at the domestic wells.

There are unexplained anomalies in the Peplow data. Although arsenic levels at the White well are consistent between the Peplow and OCHD data, levels of arsenic at other wells vary considerably between the Peplow and OCHD analyses. In general, the Peplow data are an order of magnitude higher than the OCHD data. Furthermore, the Peplow data for lead are consistently much higher than the OCHD. It is to be noted that sample blanks in the Peplow data did not always analyze as non-detect and the method of flushing or bailing each well is unknown. Some of the names in the Peplow data are unique and cannot be associated with wells or properties. For all these reasons, the Peplow data are not included in Table 2.

The OCHD data were reviewed. There is no reason to believe that the data is not valid, although laboratory data packages were not available.

Lead was not considered a contaminant of concern because of the OCHD analytical results. However, it will be addressed in recommendations. Likewise, antimony was not considered a contaminant of concern. Although it can be a health hazard, there is no evidence that it is associated with mining in the area. It apparently occurs naturally in the groundwater, and as such cannot be a criterion for an EPA Removal Action.

SECTION 5: ALTERNATIVES

The locations of the wells with the contaminated water are shown in Figure 2. From the locations relative to the topography, it is obvious that there are two possible sources of contamination:

- An unrecorded mine or naturally eroding source of arsenic in the headwaters of Mill Creek.
- The tailings pile by Alder Mill.

The first source above is unlikely. Although it is believed that the tailings pile is the source of most of the contamination, it is difficult to explain the arsenic values at the Strickland spring, which is upgradient of the tailings pile. In 1986, as part of the SI, Ecology ran extraction procedure toxicity (EP TOX) analyses on the tailings pile. EP TOX was the predecessor to the current Toxic Characteristic Leaching Procedure analysis, which indicates the leachability of contaminants from a soil matrix under acidic conditions. Ecology's EP TOX results indicate that arsenic, especially at the lower tailings pile, would leach under such conditions.

Even if the tailings pile were to be removed, the groundwater would remain contaminated for an extended duration. On a time-critical basis, EPA is supplying bottled water to affected households. This action started in January 2002 and is planned to extend to October 2002. Bottled water is expensive and does not provide for uncontaminated washing or bathing water, nor does it allow for potable water to be taken from the tap. Therefore, four less expensive and more universal alternatives for providing an

uncontaminated source of water to affected residences were investigated. These alternatives are listed in Table 3.

Each of these alternatives has advantages and disadvantages, as discussed in Section 6. Each alternative would assume connection to any dwelling or church that has water containing arsenic above the MCL. However, since the Strickland well and spring appear to contain arsenic from natural causes, they are not assessed within the alternatives.

The first three alternatives above provide for treating or otherwise providing clean water for all household uses. They are equivalent to a point of entry (POE) system. The fourth alternative provides for treated water at the point of use (POU). This would require a treatment system at each cold-water tap (if it is used for potable water). A separate system would be required at each tap for hot water, if the hot water were to be considered potable. Alternative 4 has considerable cost and implementability benefits, but requires a higher degree-of-care by the individual user to avoid drinking uncontaminated water.

SECTION 6: DISCUSSION/COMPARISON OF ALTERNATIVES

Alternative 1. Informal discussions were held with Gary McConnell, Public Works Superintendent, Twisp, Washington. He qualified his statements by saying that the town council would have to approve any new connections to the system. Criteria pertinent to any changes to the system are:

- The elevation of the water supply pipe along the main street in Twisp is elevation 1600 feet above sea level.
- Pressure at this pipe is 65 pounds per square inch (psi).
- Any new lines would need to be ductile iron, 8-inch minimum diameter.
- It would be highly desirable to provide for fire flows and to install hydrants.
- The OCHD requires 30-psi water pressure minimum at each dwelling.
- An extension of the town's system in this area would require replacement of 850 linear feet of 50-year-old 8-inch steel pipeline with new 12-inch ductile iron pipe.
- The current service area stops at Lombard Street.

A total pipe length of about 7,200 feet would be required to connect the impacted dwellings with the Twisp municipal waterline system. Additionally, a booster station would also be needed to provide adequate water pressure at higher-elevation structures. Twenty-four hydrants would need to be installed.

A cursory cost estimate was developed for this alternative and is presented in Table 4.

Alternative 2. This alternative would include drilling a community well and piping the water to the affected residences. The well would be placed relatively near the river where, based upon sample results from similarly placed wells, a high-yield uncontaminated aquifer can be accessed. Fire-flows would not be accommodated.

A total pipe length of about 5,100 linear feet would be needed. Additionally, a well and well house would be required. It is assumed that 4-inch diameter ductile iron pipe would suffice to provide water to the dwellings at adequate pressures during peak demand periods.

A cursory cost estimate was developed for this alternative and is presented in Table 5.

Alternatives 3 and 4. This alternative is for individual treatment systems at each dwelling or church.

Within this alternative, four process options were investigated. The four process options include ion exchange (IX), activated alumina (AA) filters, reverse osmosis (RO), and a proprietary Aqua-Bind® treatment devices. Since some of these treatment options have difficulty removing arsenic in the form of As(III), it is important to determine the percentage of total arsenic that occurs in the form of As(III). As(III) will require oxidation prior to treatment in order for it to be removed effectively by the selected treatment technology. A greensand prefilter can be utilized to oxidize As(III) to As(V) and also can be used to remove iron and manganese.

◆ **Treatment Technology 1: Ion Exchange**

Technology Description: IX treatment devices commonly are used to treat hard water by exchanging calcium and magnesium ions for sodium or potassium ions. The exchange of calcium and magnesium ions for sodium and potassium ions is known as the cation exchange process because these are positively charged ions. As(V) is negatively charged and thus requires anion exchange to remove the arsenic. There are two types of anion exchange resins available: strong-base anion and weak-base anion. Strong-base anion exchange resins typically are used to remove arsenic. In addition to removing arsenic, anion exchange resins will remove sulfates, nitrates, and other negatively charged ions. Because other anions compete for exchange sites, the arsenic-removal efficiency can be reduced significantly by high levels of sulfates, total dissolved solids (TDS), nitrates, fluoride, and selenium. High levels of iron in the water also can reduce the effectiveness of arsenic removal because it can bind with arsenic to form iron-arsenic complexes that cannot be removed by IX resins. When the IX resin is saturated, it must be regenerated by flushing the material with a sodium chloride solution. The waste stream from the regeneration process will contain a high concentration of arsenic. The waste brine then is discharged to a sanitary sewer or septic system (Battelle 2000).

Technology Limitations: IX exchange resins will not remove arsenic in the form of As(III), thereby requiring a pretreatment step to oxidize the As(III) to As(V) so it can be removed. Competing anions can reduce the arsenic-removal efficiency significantly and require more frequent regeneration of the anion-exchange resin. High levels of suspended solids and precipitated iron in water can clog the IX resin and could render the resin useless. To prevent the resin from clogging, another pretreatment alternative may be required if suspended solids and iron are present in the influent. Anion exchange treatment devices typically are bulky and slow, treating between 1 to 2 gallons per minute (gpm). Typically, this technology backwashes the media and discharges it to the sanitary sewer.

◆ **Treatment Technology 2: Activated Alumina Adsorption**

Technology Description: AA filters act like granular activated carbon filters in that they work through a process where ions in solution are removed by attaching themselves to available adsorption sites on an oxide surface. Because AA filters do not remove positively charged ions, minerals such as calcium and magnesium are not removed. Water is passed through a cartridge containing AA filter material until all available adsorption sites are occupied. When all adsorption sites are occupied, contaminants will pass through the system without being removed, or contaminants with a higher affinity for the adsorption sites will replace contaminants already attached to adsorption sites thus increasing the concentration of that particular contaminant in the effluent. This process is known as breakthrough. Prior to the AA filter becoming saturated with contaminants, the filter material must be replaced.

Technology Limitations: The AA adsorption process is very sensitive to pH. AA filters work best on water with a low pH, between 5.5 and 6.0. Above a pH of 6, the performance of the AA filter rapidly deteriorates and will not work on water with a pH greater than 8.2¹ (Battelle 2000).

Again, the oxidation state of arsenic impacts the removal efficiency of the filter. As(III) can be removed from solution, however, breakthrough occurs more rapidly than with water containing As(V). An AA filter will preferentially select for As(V) over As(III). In addition to removing arsenic from water, AA filters also can remove

fluoride, lead, selenium, silica, and TDS. Because AA filters remove more than just arsenic, there is competition for adsorption sites. Although the selectivity for arsenic is greater in AA filters than in IX treatment devices, ions such as hydroxides, sulfates, silica, and selenium will be preferentially removed before As(III) will be removed. Because of this As(III) should be oxidized to As(V) prior to treatment to insure its removal (Battelle 2000).

Like IX treatment devices, AA filters can be bulky and slow, treating between 1 to 2 gpm. Disposal of the filter also is an issue as the filter media may require analytical testing before it can be accepted at a non-hazardous waste landfill.

◆ **Treatment Technology 3: AAqua-Bind®**

Technology Description: The unit is installed like a filter, with connections to the well, drinking water system, and sewer system. The media is proprietary. Manufacturer's literature states the following:

- Up to a 99% arsenic removal efficiency for As(III) or As(V);
- Media life 6 months to 1 year;
- Media can be disposed as non-hazardous waste.

Technology Limitations: If hardness and other parameters exceed criteria, pre-treatment may be necessary. The system uses a timed backwash to clean the media. Backwash water is discharged to the sewer system.

Aqua-Bind units can treat 3 to 7 gallons of water per minute. The capabilities of this technology would need to be verified by actual use; this is considered an experimental technology.

◆ **Treatment Technology 4: Reverse Osmosis**

Technology Description: RO is a process that forces raw water through a semi-permeable membrane whose pores are sized such that only molecules the size of water or smaller can pass through them. Pressure in the water line forces water molecules through the pores in the membrane while larger molecules stay behind to be discharged to a sewer or septic system. Much of the water entering an RO system is rejected or used to rinse the contaminants off of the filter. It can take 3 to 10 gallons of water to produce 1 gallon of treated water. The water rejected in the process is discharged to the sewer or septic system. To prevent contamination of the treatment unit by the sanitary drain, an air gap between the drain and the treatment unit must be utilized. Most commercially available RO units come equipped with the following:

- A mechanical prefilter to remove sediment and suspended solids;
- An activated carbon filter to remove organics and chlorine;
- An RO module that contains either a cellulose acetate or a thin film composite membrane to remove additional contaminants; and
- A pressurized storage tank with a separate faucet.

RO is a POU technology and will not treat all of the water used in a home. Residential RO units are used solely for drinking and cooking purposes and typically are installed under the kitchen sink. Purified water from the RO unit can be distributed to other rooms from the kitchen unit by connecting the kitchen unit to pressurized storage tanks and faucets in other rooms where water is used for consumption.

Technology Limitations: At a minimum, an RO unit requires 40 psi of water pressure to work effectively. A large quantity of water also is required to generate treated water. For one gallon of treated water upwards of 10 gallons of water may be used to produce the treated water.

Water hardness negatively impacts the performance of the RO membrane. Water entering the RO unit

should be softened if water hardness is over 10 grains, or 171 milligrams per liter calcium carbonate. Also, if water contains chlorine or iron, these can clog the pores in the membrane and damage it. Suspended solids also should be removed prior to contacting the RO membrane or else they can damage the membrane.

RO units are slow and typically generate 7 to 25 gallons of treated water per day.

Comparison of Process Options: A comparison of the four process options, in light of the existing conditions, reveals the following:

- RO has advantages concerning overall removal efficiency, which can be as high as 95%, but its slow treatment speed and water usage (process water) per useable gallon of water makes it suitable for POU only. This process water usage, which would contain the arsenic removed from the drinking water, would need to be discharged to each structure's sanitary disposal system, which is assumed to be a leach field. This would probably exceed the capacity of the leach field. For these reasons, RO is dropped from further consideration as a POE technology. It is selected, with pretreatment, as the POU technology for Alternative 4.
- For POE treatment, activated alumina appears to have technical advantages over ion exchange. However, disposal of the media may be problematic. For costing purposes, activated alumina is selected as the process option for Alternative 3.

Costs for Alternatives 3 and 4 are presented on Tables 6 and 7, respectively. All four alternatives are compared to one another in Table 8. For all alternatives, it has been assumed that:

- Fifteen dwelling units would be connected/treated.
- For POU (Alternative 4), two separate taps would be treated.
- EPA would fund the capital costs. Individual property owners would pay for the annual costs.

SECTION 7: RECOMMENDATIONS

Contaminated Wells

- POU treatment units at individual dwellings are the most economical alternative and can be implemented rapidly. A separate POE water softener would be included at each dwelling. This is a recommended removal action.
- As part of the removal, but prior to installation of units, the following needs to be accomplished:
 - 1 A complete metals suite chemical analysis at each well, also including arsenic speciation, hardness, pH, sulfates, TDS, nitrates, fluoride, and selenium.
 - 2 Review of the above analyses to determine if pretreatment is required.
 - 3 Meeting with individual dwelling owners to determine where the units will be located. If there is insufficient room within the dwelling, a separate insulated and heated annex (shed) will be needed to contain the water softener. Costs for this shed have not been included in the estimates.

Continued Monitoring

- Establish a program of periodic monitoring (initially quarterly) of water quality at the well and water quality at the tap.
- Include analysis of antimony and mercury, as well as other pertinent analytes, in future periodic sampling. Mercury was used in early gold mining operations. There is some amount of mercury in the tailings pile. Therefore, it should be included in the analyses for the first two monitoring periods, and then dropped if it is not detected.
- Establish a database where all monitoring results from all agencies would be aggregated together. Ambiguous data, such as differing names on the same well, should be researched and

clarified where possible. This database should be accessible by all agencies or private entities involved. The OCHD has developed part of this using geographic information system (GIS) software.

Tailings Pile

- There is strong evidence that the tailings piles, especially the lower one, are the source of much of the groundwater contamination.
- Discussions should be held with Ecology concerning their efforts to find a potentially responsible party (PRP), and the PRP's willingness to implement removal actions.
- If a viable and willing PRP is not found, develop an addendum to this removal action memo. The addendum would address options to eliminate the tailings piles as sources of groundwater contamination.

SECTION 8: REFERENCES

Battelle, October 2000, *Arsenic Removal from Drinking Water by Ion Exchange and Activated Alumina Plants*, EPA/600/R-00/088, by Lili Wang, Abraham Chen, and Keith Fields, under Contract No. 68-C7-0008 Work Assignment Number 3-09, prepared for the United States Environmental Protection Agency, National Risk Management Research Laboratory, Office of Research and Development, Cincinnati, Ohio.

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World Health Organization (WHO), February 12, 2002, *inf@who.int, Arsenic in Drinking Water, Fact Sheet No. 210*

¹A pH of 8.2 is the point where an AA filter has no charge, otherwise known as the zero point charge (Battelle 2000).